Microcredit from Delayed Bill Payments

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Abstract

Delaying bill payments to public utilities may provide an important source of credit to households. With billing data from a water utility in Manila, Philippines, this paper builds a consumption and savings model to estimate demand for both water and credit. Estimates suggest that households value billing flexibilityfrom the water utility as much as 7% of an average water bill. I then analyze the welfare effects of popular proposals to reduce delinquency by requiring upfront payments. Simulations find that upfront payments do not produce enough cost savings to justify their negative impacts on household consumption smoothing.

What kind of flexibility, temporal?

A does this mean being able to not pay? under what terms?

A to whom?

"Recoup less revenue

Keywords: credit constraints; consumption smoothing; water utilities.
JEL Codes: O13; E21; L95.

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1. Introduction

Households face a dynamic problem of how to smooth their consumption over time, especially in low-income settings where households have little access to formal credit and risky income streams (Morduch [1995]). Households often resort to costly money lenders or informal arrangements with family members (Banerjee and Duflo [2007]). Firms may provide an additional channel for consumption smoothing by allowing households to delay their payments for goods and services. In particular, public utilities often tolerate high levels of delinquent bills each month. Delinquent bills provide an economically important source of credit for households since public utilities cover broad populations and take up at least 5% of household incomes in developing countries.[1]

A approximately?

When market failures limit formal lending, public utilities may provide efficient, second-best sources of credit.First, poor access to collateral often restricts the availability of lending options to low-income households (Jack et al. [2016]). Public utilities overcome this barrier by threatening disconnection from future service to enforce repayment. Second, poor infrastructure and mobile populations increase the transaction costs of screening and monitoring debtors, which contribute to high interest rates (Jack and Suri [2014]). As part of their business practices, public utilities invest in meter reading and billing systems that may lower these transaction costs. Third, moneylenders and peer-to-peer lending groups often cater to small pools of debtors while public utilities are able to spread default risk across a wide customer base. Despite these advantages, linking credit to consumption from public utilities creates an inherent inefficiency by incentivizing overconsumption. For example, households may substitute toward piped water and away from other beverages in months where they are credit constrained.Since governments actively regulate public utilities, the extent to which public utilities should provide credit remains an open policy question (Laffont [2005]).

A second best to whom? maybe add a footnote?

A formal?

A absent externalities from water consumption? mention in footnote

Technologies that eliminate delayed payments have recently dominated utility policy discussions. Both researchers and policymakers recommend new prepaid metering technologies, which require upfront payments before releasing any services, as effective strategies to prevent nonpayment.[2] Yet, existing analyses have yet to consider how these technologies may impact household welfare by reducing consumption smooth-

[1] Komives et al. [2006] find that households spend 1-2% of their incomes on water and 4% on electricity.

[2] Kojima and Trimble [2016] and Heymans et al. [2014] point to prepaid metering as a successful strategy to reduce nonpayment for electricity and water utilities (respectively). Jack and Smith [2016] find that prepaid meters for electricity in South Africa substantially increase utility revenues.

ing.

This paper incorporates delayed payments to public utilities into household consumption and savings decisions in order to evaluate the welfare effects of offering credit through public utilities. I build a dynamic model where each period, households have the option of borrowing with a costly asset as well as with delayed payments to a public utility. Low interest rates on delayed payments induce households to increase their borrowing by overconsuming utility services. The extent to which households value payment flexibility depends on the borrowing costs of other assets, which are often difficult to measure in traditional survey data.

To estimate borrowing costs, I take a structural approach using billing data from a regulated water utility in Manila, Philippines. The identification strategy leverages months where utility workers visit households and disconnect them if they do not pay their outstanding balances. If borrowing were costless, households would never be disconnected during these visits because they would pay their outstanding balances with cheap loans. Therefore, long and frequent disconnections in response to these visits — especially among households with large outstanding balances — provide evidence of borrowing costs. Using this strategy, I estimate high interest rates for borrowing, consistent with poor observed access to formal credit in Manila with only 3.9% of households having credit cards and 18.7% having bank accounts.[3]

These estimates also allow me to simulate several counterfactual policies. First, I find that in a counterfactual where households are required to pay their bills on time (holding all else equal), consumer welfare drops by 50.3 PhP (or 1.1 USD) per household-month, which is equal to 7% of an average water bill. Usage also declines since households no longer have an incentive to overconsume water to fund their borrowing from delaying bill payments.

Second, I simulate a policy that (1) eliminates delayed payments by charging a high interest rate on unpaid bills, (2) eliminates default risk by preventing households from leaving large outstanding balances when they permanently disconnect, and (3) adjusts prices to ensure that the water utility remains revenue-neutral (consistent with regulation in Manila).[4] Without default risk, the utility has fewer costs to recover with prices. Yet without billing flexibility, households use less water, generating less revenue for the utility. On net, prices remain the same and the policy reduces social welfare by 51.1 PhP (or 1.1 USD) per household-month.

A so there's 2 things going on here, right? 1. i get credit by not paying my bill on my fixed consumption c 2. more credit by not paying and consuming

[3] Statistics are from the Philippines 2014 Consumer Finance Survey.

[4] Laffont [2005] discusses economic reasons for these regulatory structures which are common in both developed and developing country settings.

Finally, I use this framework to evaluate implementing prepaid meters in this context. While ensuring that households pay upfront, prepaid meters require steep increases in prices to cover their installation and maintenance costs. As a result, prepaid meters produce large reductions in social welfare on the order of 225.2 PhP (or 5.0 USD) per household-month. Taken together, these results suggest that popular policies to reduce nonpayment may be welfare reducing primarily by limiting consumption smoothing.Given around 2.4 million piped water using households in Metro Manila, these policies would imply welfare costs on the order of 32.7 to 144.1 million US dollars per year.

Decompose loss due to cost and due to consumption smoothing?

This paper contributes to three main strands of economic literature. First, this paper brings payment and billing policy questions into a growing literature on optimal policy for utilities in developing countries (McRae [2015]; Szabó [2015]; Jack and Smith [2016]; Jack and Smith [2015]; Szabó and Ujhelyi [2015]). Building on previous static models, this paper also provides a framework for considering how dynamic incentives affect household demand for public utilities. Second, this paper draws on a large body of research analyzing household credit constraints, particularly through microfinance interventions (Morduch [1999]; Morduch [1995]; Cull et al. [2009]; Dupas and Robinson [2013b]; Jack et al. [2016]). Karlan and Zinman [2009] and Giné and Karlan [2014] specifically focus on microfinance in the Philippines. Third, Deaton [1991] provides the foundational model of dynamic decision-making that serves as the starting point for the model in this paper, and the estimation of this model adapts methods developed by Gourinchas and Parker [2002] and Laibson et al. [2007].

D how many are affected by law?

This paper proceeds with Section 2 describing the water billing data from Manila. Billing practices, disconnection policies, and institutional details are discussed in Section 3 alongside descriptive evidence. Section 4 develops a model of household consumption and savings decisions while Section 5 discusses the estimation and results. Counterfactual exercises and welfare impacts are provided in Section 6. Section 7 concludes.

non-pay correlated with other non-pay? possibility of bribery?

2. Data

Measuring creditab wt through delayed water bill payments requires information on water consumption and bill payments at the household-level as well as features of the credit environment in Manila.

Water consumption and bill payments come from water utility records collected as part of a research partnership with one of the two regulated utilities in Metro Manila, Philippines where each utility is responsible for serving their assigned geographic half of Metro Manila. This utility provided access to monthly billing records for each connection as well as detailed information covering the regulatory structure and costs of production. Monthly billing records include meter readings, billing amount, outstanding balances, and payments spanning January, 2008 to May, 2015.

Disconnection is defined as months with missing values for usage. Months with zero recorded consumption are not considered disconnected. Since households face a 200 PhP reconnection charge but a

Over this period, the total number of connections increased from 900,000 to 1,500,000 as the water utility expanded service access. Water connections are split into four categories: residential (90%), semi-business (4%), commercial (5%), and industrial (1%).

To examine household demographics, connections are linked to a water connection survey conducted independently to monitor the quality of the utility's service. The survey randomly interviewed households with water connections covering 15,000 households in 2008, 24,000 households in 2010, and 23,000 households in 2012. Since the survey followed a similar sampling design across rounds, 13% of households were interviewed in two waves and 1.4% of households were interviewed in three waves while remaining households were interviewed in one wave. To focus on household decisions, the analysis includes only residential connections that are identified in this survey as serving a single household (31% of all connections). The connection survey also includes demographics for households that own their water connections. Households using connections alone tend to be larger and wealthier than households that share connections with other households according to previous research (Violette [2019]). Table 7 in Appendix 8.1 includes more details on how the final sample is constructed for the analysis.

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Since the analysis focuses on the borrowing and savings behavior of a representative household, additional data sources help characterize credit access in Manila. Average household income is calculated using the 2015 Family Income and Expenditure Survey, which covers 4,130 households in Metro Manila. Interest rates for borrowing and saving come from the 2014 Consumer Finance Survey in Metro Manila as well as the World Bank Databank (2010-2015) for the Philippines.

3. Credit through Delayed Water Bill Payments

In Manila, Households have poor access to credit: 1% have credit cards, 3.8% have auto-loans, 0.5% have mortgages, and 12% have all-purpose loans (of which 61% are from money lenders and 15% are from micro-finance groups).[5] All-purpose loans charge high monthly interest rates of 9.5% on average.

Delaying water bill payments may provide a reliable source of low-cost credit to households because the water utility often tolerates high rates of delinquency before disconnecting water service and the utility is prohibited from charging any interest on outstanding balances. Consistent with this theory, households are 56 days behind in their payments on average. Households also make large, infrequent payments. Table 1 provides summary statistics on household consumption, billing, and payments. While the average bill is 671 PhP per month, payment sizes average 901 PhP and households make payments in only 71% of months. These payment patterns leave an average total outstanding balance of 1,206 PhP per month. With average monthly incomes of 21,907 PhP, households spend around 2% of their income on water while unpaid water bills total around 3.5% of their income.[6] In comparison, all-purpose loans average 51,280 PhP with an average period of 9 months.[7]

The utility enforces payment by visiting households and disconnecting them if they do not immediately pay their bills.[8] While households often try to negotiate for additional time to pay their bills, 96% of households report having to pay within 30 days and the average grace period is only 13 days. As a result, only 25% of households report having "enough time" to make their payments, which may be in part due to poor credit access in Manila. While disconnected, households likely substitute to alternative water sources including sharing with neighbors, using from deepwells, or purchasing from local water vendors. In the 2012 wave of the water connection survey, 6.1% of households report having been disconnected for delinquency. The billing data find that even among households that remain connected at the end of the sample, 2% of their months on average are spent temporarily disconnected. To reconnect, households must pay any outstanding bills as well as 200 PhP reconnection fee.

The utility must frequently enforce payments because the utility often cannot recover unpaid bills once households have permanently disconnected. 7.5% of house-

[5] Author's calculations from the 2014 Consumer Finance Survey.
[6] Author's calculations with the 2015 Family Income and Expenditure Survey.
[7] For reference, 1 USD is worth around 45 PhP over this period.
[8] Disconnection typically involves placing a metal lock on the water meter that stops any flow.

holds remain disconnected at the end of the sample, which are identified as "permanently disconnected" households. 79% of these households leave large outstanding balances that are never repaid averaging 7,119 PhP, which is over 10 times the average water bill. The remaining 21% pay their full balances upon disconnecting possibly because they plan to move to another dwelling within the utility's service area. Since 0.13% of households permanently disconnect each month on average,[9] then the average household remains connected for around 32 years assuming a constant rate over time.[10] Therefore, unpaid outstanding balances average 18.5 PhP per household-month or 2.8% of water bills.

Due to scarce resources, the utility is unable to visit every delinquent household each month. Instead, workers sweep periodically through neighborhoods of around 200 households and issue direct warnings to especially delinquent households.[11] On average, households receive 0.4 direct warnings over the course of the sample. 72% of warnings result in immediate payment while 28% result in disconnection within two months. For these disconnected households, 64% eventually reconnect in an average of 6.7 months. The remaining 36% remain disconnected for the sample period.

Even households that do not receive direct warnings increase their bill payments when nearby households receive direct warnings as part of a neighborhood sweep.[12] While data do not record occurrences of sweeps, frequent direct warnings suggest that sweeps are common events. On average, neighborhoods experience at least one warning in 57% of months and at least five warnings in 17% of months. Warnings appear to occur at uneven intervals, which suggests that neighborhood sweeps may be difficult for households to predict with precision.

Households may also pay their water bills infrequently for other reasons aside from accessing low-cost credit. First, households may not be aware of the size or due date for each water bill. The utility addresses this problem by sending meter readers to record monthly consumption, deliver each bill in person, and educate households about their payment options. Second, households may experience time or hassle costs in making

[9] The disconnection rate is calculated (1) for households that connect between 2007 and 2011, which covers the connection survey and (2) for disconnections occurring between Jan, 2012 and May, 2014 to ensure that any disconnections last for at least a year before the sample ends in June, 2015.

[10] This constant rate is consistent with a weak observed correlation between the permanent disconnection rate and calendar months of -0.0033.

[11] Neighborhoods refer to areas defined internally by the utility as "Meter Reading Units." The utility has adopted a decentralized organizational structure by assigning one worker to manage each meter reading unit.

[12] Appendix 8.2 also finds that households do not increase payments in response to warnings for nearby households in separate neighborhoods.

Table 1. Mean Characteristics

	Mean	Std. Dev.	Min	25th	75th	Max
Usage (m3)	24.3	15.4	0.0	14.0	31.0	200.0
Bill	671	734	-4,640	265	843	19,999
Unpaid Balance	1,206	3,316	-9,965	0	1,044	79,904
Share of Months with Payment	0.71	0.45	0.00	0.00	1.00	1.00
Payment Size	901	1,067	0	313	1,070	49,688
Days Delinquent	56.2	113.7	0.0	0.0	61.0	750.0
Delinquency Visits per HH	0.40	0.70	0.00	0.00	1.00	6.00
Share of Months Disconnected	0.04	0.18	0.00	0.00	0.00	1.00

45 PhP ~ 1 USD Std. Dev. refers to standard deviation. 25th and 75th refer to percentiles. Bills, Unpaid Balances, and Payment Sizes are in PhP per household-month. Negative bills and balances generally arise from refunds for billing or payment errors. See Appendix 8.1 for more details on the sample construction.

each payment, which may naturally lead households to pay infrequently. The utility reduces these costs by offering many different payment options.[13] Third, previous research has documented how negative opinions toward public utilities or local governments can increase delinquency [Szabó and Ujhelyi, 2015]. In Manila, the utility enjoys largely positive public opinion because the water utility in Manila represents a public-private partnership that has dramatically improved service since taking over from the previous government utility.[14]

Unlike these other reasons for delinquency, the credit mechanism predicts that households with volatile incomes may time their bill payments to smooth their consumption over time (Deaton [1991]). The following equation tests whether income is more correlated with bill payments than with consumption by using changes in the number of working household members as a proxy for income shocks

$$\Delta Y_{ht} = \beta_0 + \beta_1 \Delta\textsc{Working Members}_{ht} + \beta_2 \Delta\textsc{Total Members}_{ht} + \varepsilon_{ht}$$

where $\Delta\textsc{Working Members}_{ht}$ is the change in working household members and $\Delta\textsc{Total Members}_{ht}$ is the change in total household members between each survey round, t and for each household, h. ΔY_{bq} includes four outcomes measured as changes:

[13] 79% of households use small payment centers (mall kiosks, gas stations, convenience stores, etc.), 17% of households pay at local utility offices, and 3% of households pay over the phone, online, or via ATM kiosks according to the connection survey.

[14] The connection survey conducts an independent assessment of people's satisfaction with the utility finding that over 95% of households rate the utility as "good" or "very good" as opposed to "fair," "poor," or "very poor" in terms of overall service quality.

water consumption (measured by the water bill in PhP), water bill payments (in PhP), disconnection status, as well as monthly household income, which is measured in the household survey from Pasay City. Standard errors are clustered at the household-level.

Table 2. Correlations of Household Working Members and Total Members with Consumption, Payments, and Income

	(1) Δ Consumption	(2) Δ Payment	(3) Δ Income
Δ Working Members	6.68	40.44[a]	4920.00[a]
	(8.33)	(15.35)	(132.41)
Δ Total Members	23.05[a]	1.76	1480.07[a]
	(5.84)	(10.43)	(72.07)
Mean	565.02	553.05	21,663.21
R^2	0.010	0.003	0.143
N	4,788	4,808	21,374

Outcomes are in PhP per month and household members are reported in the 2008-2012 connection survey. Standard errors are clustered by household. Income changes exclude top and bottom 1% outliers. [c] $p<0.10$, [b] $p<0.05$, [a] $p<0.01$

Column (1) of Table 2 finds a large statistically significant correlation between total household members and consumption as well as a very small, statistically insignificant correlation between employed members and consumption. This finding suggests both that the number of household members is a key driver of water demand and that changes in household income have little impact on water consumption. Column (2) finds the opposite pattern for payments where employed members drive large increases in payments while total household members exhibit almost zero correlation. Consistent with Column (2), disconnection patterns in Column (3) suggest that adding an additional employed household member reduces the probability that a household is disconnected by 2% which is economically significant given an average disconnection rate of 13%. Column (4) finds that working household members correlated much more strongly with household income than the total number of household members. Comparing results from Column (2) and (4), estimates suggest that in response to income shocks, households spend almost one out of every 100 PhP on outstanding bills. These results provide suggestive evidence of consumption smoothing where households flexibly adjust their payment patterns in response to income shocks without changing their water consumption.

Appendix 8.5 confirms similar results by linking the age, education, and location of connection owners to average changes in earnings for people with the same demographics from quarterly Labor Force Surveys. This exercise suggests that consumption smoothing patterns may be robust to using household employment changes as proxies for income shocks.

4. A Model of Borrowing, Saving, and Water Use

To quantify the implications of different billing policies for household welfare, I construct a simple model of household borrowing, saving, and water consumption decisions over time. This approach builds on a standard buffer-stock savings model as developed by Deaton [1991].

In this model, households first move to Manila and begin consuming piped water. As households receive positive income shocks, they accumulate precautionary savings to insure against future negative income shocks. In these months, households simply consume water according to their preferences and pay their bills.

When households receive enough negative income shocks, they spend their savings and begin to borrow. First, households borrow by not paying their current water bills because they face zero interest rates on unpaid bills. Each successive month, households can increase this debt by continuing to consume water without paying.

Further negative income shocks may induce households to borrow beyond their current water bill at which point they face a trade-off: borrowing from a standard asset at a high interest rate, or further increasing their water consumption to expand the size of their unpaid bills. For example, instead of taking out a costly loan from a moneylender, households may choose to wash clothes at home instead of at a laundromat or drink water instead of other beverages while leaving their bills unpaid. As substitution toward piped water becomes increasingly costly, households borrow from the standard asset.

With some probability, the utility conducts delinquency warnings, which confront indebted households with a choice: pay their debts or disconnect and use an alternative water source. Since the alternative water source may involve an additional fixed cost each month, households with small debts simply prefer to pay their debts and stay connected either by taking out a costly loan or by lowering their consumption this month. Households with large debts decide to disconnect in order to avoid taking out a large loan or experiencing a sharp drop in consumption this month. Once disconnected, households begin accumulating savings to eventually pay their debts and reconnect to service.

At some point, households learn whether they will move to a new dwelling in Manila or leave Manila. Households that plan to stay in Manila must pay their full balance before moving because it is likely that the utility will recognize them at their new address. Households that plan to leave Manila do not need to bay their outstanding debts before leaving. Therefore just before changing dwellings, these households have an incentive to accumulate large unpaid bills since the utility is unable to collect on these bills if households leave Manila. In these months, households may also have a strong incentive to disconnect in response to delinquency warnings.

To formally model household borrowing and savings decisions, I start from a standard intertemporal utility maximization problem as developed by Deaton [1991]. This approach assumes a finite time horizon where households choose water usage, borrowing, and savings in each month to maximize current and expected future utility.

Households first move to Manila in month 1 and then choose their consumption of water and other goods as well as how much to borrow and save each month until they leave the city in month T. Household expected utility in each month t is given by the following equation

$$\begin{aligned} &E_t\Big[\sum_{\tau=t}^{T}(1+\delta)^{t-\tau}\,\frac{u(w_\tau,x_\tau)^{1-\gamma}}{1-\gamma}\Big] \\ &u(w_\tau,x_\tau) = x_\tau - \frac{1}{2}(w_\tau-\alpha)^2 \end{aligned} \tag{1}$$

where households have a rate of time preference $\delta \in (0,1)$. Households have quadratic preferences over water consumption, w_t, and a bundle of other goods, x_t. α captures household's water satiation point each month, capturing the intuition that households are likely to consume a finite amount of water even if the price is zero. Quadratic preferences also assume that income has no effect on consumption consistent with descriptive evidence that fluctuations in household employment are uncorrelated with water spending. Households are assumed to have constant relative risk aversion for consumption across months given by γ.

In each month, households face a budget constraint as follows

$$x_t + pw_t = y_t - (1-C_{t+1})f + A_t - \frac{A_{t+1}}{1+r} + B_t - B_{t+1} \tag{2}$$

where p captures the price of water, which is assumed to depend linearly on water consumption to approximate the tariff in Manila, $p = p_1 + p_2 w_t$. The price of the bundle of other goods, x_t, is normalized to one. y_t represents household income each month which takes a value of $(1+\theta)\bar{y}$ with probability π and a value of $(1-\theta)\bar{y}$ with probability $(1-\pi)$ where $\pi \in (0,1)$ and $\theta \in (0,1)$.

Households choose whether to remain connected in the next month given by C_{t+1}. When households are disconnected ($C_{t+1} = 0$), they are assumed to face fixed cost f each month. Since temporarily disconnected households are likely to share with neighbors or purchase from local vendors who resell piped water, they are assumed to face the same marginal prices as connected households.

Households can use asset, A, for borrowing and saving. A_t captures debt (when $A_t < 0$) or savings (when $A_t > 0$) inherited from the previous month. A_{t+1} captures how much debt or savings to pass onto the following month. Households are assumed to earn zero interest from saving consistent with low access to interest-bearing bank accounts in Manila.[15] Households face interest rate r_h when borrowing so that $r = r_h$ if $A_{t+1} < 0$ (and $r = 0$ if $A_{t+1} \geq 0$). Households are assumed to pay all debts or enjoy all savings from this asset before leaving Manila so that $A_T = 0$. Households are also assumed to face a borrowing constraint such that $A_{t+1} \geq \overline{A}$, which prevents households from infinitely borrowing.

Households can also borrow by delaying payments to their water bills. B_t (≤ 0) captures unpaid bills inherited from the previous month. B_{t+1} (≤ 0) describes how much water debt to pass onto the following month (by delaying payment of the current bill). Households must satisfy the following borrowing constraint each month, which ensures that water debt must be less than this month's bill and unpaid bills from previous months

$$B_{t+1} \geq (1-v_t)C_t C_{t+1}(B_t - pw_t) + (1-C_{t+1})B_t \geq \overline{B} \tag{3}$$

The choice of B_{t+1} depends on whether households receive a delinquency warning, v_t, which occurs with probability $\lambda \in (0,1)$ and is assumed to be independent of the two income states. The choice of B_{t+1} also depends on whether households are connected to piped water, C_t, and choose to remain connected in the next month, C_{t+1}.

The borrowing constraint creates the following four cases:

Case 1: If there is no delinquency warning ($v_t = 0$) and the household is connected

[15] Among households in the 2014 Consumer Finance Survey, 21% have bank accounts, 14% have bank accounts that pay interest, and 6% have accounts that pay interest and balances over 10,000 PhP, which is the minimum balance need to earn interest. The Philippines National Bank lists an interest rate of 0.1% on savings accounts above 10,000 PhP (accessed Jan. 28th, 2020).

($C_t = 1$) and chooses to stay connected ($C_{t+1} = 1$), then the household can borrow up to their existing water debt plus their bill this month so that the borrowing constraint equals $B_{t+1} \geq B_t - pw_t$.[16]

Case 2: If there is a delinquency warning ($v_t = 1$) and the household is connected ($C_t = 1$) and chooses to stay connected ($C_{t+1} = 1$), then the household needs to pay their existing debt and cannot borrow from their water bill this month so that $B_{t+1} = 0$.

Case 3: If the household chooses to be disconnected in the next month ($C_{t+1} = 0$) likely in response to a delinquency warning, then the household avoids paying the existing debt but faces an additional fixed cost of f per month to use a temporary water source. In this case, the borrowing constraint reduces to $B_{t+1} \geq B_t$ ensuring that households can only borrow up to their existing water debt.

Case 4: If the household is disconnected ($C_t = 0$) and chooses to reconnect ($C_{t+1} = 1$), then the household needs to pay off their existing debt and cannot borrow from their water bill this month so that $B_{t+1} = 0$.

Households also face an additional borrowing constraint, $B_{t+1} \geq \overline{B}$, which prevents households from borrowing indefinitely.

In the month $\overline{T}$, households learn where they will move at time T. With probability χ, households learn that they will move to a new home in Manila at time T in which case the need to pay their outstanding bills before moving (ie. $B_T = 0$). With probability $(1 - \chi)$, they will leave Manila at time T in which case they can leave bills unpaid with no consequence (ie. $0 \geq B_T \geq \overline{B}$).

The household's maximization problem can then be written recursively where households solve for a value function, $V_t(.)$, over four possible independent states given by s_t: (1) high income and delinquency warning with probability $\pi\lambda$, (2) high income and no delinquency warning with probability $\pi(1 - \lambda)$, (3) low income and delinquency warning with probability $(1 - \pi)\lambda$, and (4) low income and no delinquency warning with probability $(1-\pi)(1-\lambda)$. Given these states, the recursive problem can be written as follows

$$\begin{aligned} V_t(X_t, s_t) &= max_{w_t, x_t} \ \frac{u(w_\tau, x_\tau)^{1-\gamma}}{1-\gamma} + (1+\delta)^{-1} E\Big[V(X_{t+1}, s_{t+1}) \Big] \\ X_t &= [w_t, x_t, A_{t+1}, B_{t+1}, C_{t+1}] \end{aligned} \tag{4}$$

with equations (2) and (3) holding each month.[17] This problem can be solved in two

[16]Note: borrowing is given by negative values for B_t and B_{t+1}

[17]At time $\overline{T}$, households learn about whether they will move *in* or *out* of Manila at time, T, meaning that

steps:

Step 1: For each possible choice of assets, A_{t+1} and B_{t+1}, and connection status, C_{t+1}, households maximize utility over water, w_t, and other goods, x_t, subject to their budget constraint and borrowing constraint. Within each month, households maximize utility given by $x_t - \frac{1}{2}(w_t - \alpha)^2$ such that the budget constraint and borrowing constraint hold. When the borrowing constraint does not bind, then households reach an interior solution given by $w_t^* = \frac{\alpha - p_1}{2p_2+1}$. The borrowing constraint does not bind when connected households have small unpaid bills (ie. B_{t+1} is small). Households also consume w_t^* in months where w_t does not affect the borrowing constraint such as when households are disconnected or when households receive delinquency warnings.

When connected households want to use large unpaid bills as a source of credit (ie. B_{t+1} is very negative), then the interior solution, w_t^*, may be too small to satisfy the borrowing constraint. Let $\overline{w}_t$ denote water consumption that just satisfies the borrowing constraint so that the bill this month, $-(p_1 + p_2\overline{w}_t)\overline{w}_t$ equals demand for additional borrowing, $B_{t+1} - B_t$ which gives $\overline{w}_t = \frac{(p_1^2 - 4p_2(B_{t+1}-B_t))^{.5} - p_1}{2p_2}$. When $w_t^* = \overline{w}_t$, the interior solution just satisfies the borrowing constraint. When $w_t^* < \overline{w}_t$, the interior solution is unable to satisfy the borrowing constraint so households consume $\overline{w}_t$. When $w_t^* > \overline{w}_t$, the interior solution more than satisfies the constraint so households consume w_t^*.

Step 2: Given optimal consumption choices of w_t and x_t, households then choose their assets and whether to remain connected each month to maximize $V_t(.)$. $V_t(.)$ can be solved by working backwards from month T where $A_T = 0$. Since households are assumed to have positive time preferences ($\delta > 0$) and zero interest on their savings, households have an incentive to consume their initial assets until they reach their borrowing constraints (Deaton [1991]).

5. Estimation and Results

Quantifying the welfare consequences of different billing policies requires estimates of household preferences, the relative cost of an alternative water sources, and the rate at which households receive delinquency warnings since neighborhood sweeps of delinquent households are unobserved in the data. The empirical strategy matches simulated consumption and payment for a representative household to average characteristics in the billing data. This strategy estimates the preference for water α from observed water consumption. The rate of delinquency warnings λ are estimated from

$E\Big[V(X_{t+1}, s_{t+1})\Big] = \chi E\Big[V_{in}(X_{t+1}, s_{t+1})\Big] + (1-\chi)E\Big[V_{out}(X_{t+1}, s_{t+1})\Big].$

the level of observed unpaid water bills. Frequent delinquency warnings reduce the incentive for households to accumulate unpaid water bills. The fixed cost of using an alternative water source f is identified by the observed share of households that temporarily disconnect in response to delinquency warnings. Higher fixed costs discourage households from disconnecting when they receive a delinquency warning.

The empirical strategy requires calibrating prices, income, and interest rates to match economic conditions for the average household in Manila. The strategy uses a fixed price per m^3 of $p_1 = 17.5$ PhP and a marginal increase in price per m^3 of $p_2 = 0.29$ PhP, which together reflect the linear function that best fits the increasing tariff in Manila as shown in Appendix Table 9.[18] This approximation captures how prices increase with usage while also allowing for computational tractability within the dynamic model.[19]

Mean monthly income, $\overline{y}$, is calibrated to average income in the household survey of Pasay City, taking a value of 21,907 PhP. Using panel structure between 2008 and 2011 in the same survey, monthly variation in income, θ, is calculated by dividing the standard deviation of household income net of household fixed effects by mean income for a value of 0.52. For θ to capture monthly income variation within households, this calibration requires the assumption that reported income changes between 2008 and 2011 are representative of monthly income changes for households. This estimate for θ falls within range of previous estimates in the literature.[20] Households are also assumed to face even probabilities of high or low income realizations each month, which implies that π equals 0.5. The monthly interest rate on borrowing from standard assets is calibrated to equal 9.5% according to reported rates for "all-purpose" loans from the Consumer Finance Survey for Metro Manila. The majority of these loans are issued from money lenders.

The estimation also assumes parameters for household time-preferences. First, the monthly discount rate δ is assumed to equal 0.005, which implies an annual discount rate of around 6%. This discount rate is in range of estimates from similar structural

[18] Appendix 8.4 includes more details on this calculation.

[19] Violette [2019] and Szabó [2015] carefully capture non-linear pricing incentives with static models, which are computationally expensive. The linear approximation also parallels average pricing models of consumer demand for utilities as suggested by Ito [2014].

[20] θ can also be interpreted as measuring the coefficient of variation (CV), which measures the standard deviation of monthly household income divided by average household income (Hannagan and Morduch [2015]). Hannagan and Morduch [2015] use monthly financial diaries in the US to calculate CVs of 0.39 for average households and 0.55 for households below the poverty line. Using household surveys from Mexico, Amuedo-Dorantes and Pozo [2011] calculate CVs between 0.29 and 0.46.

dynamic models.[21] Second, the coefficient of relative risk aversion γ is set equal to 1, which is approximated by the natural logarithm and falls within a wide range of estimates from the literature.[22]

Households are assumed to remain at their dwelling for $T = 384$ months before disconnecting, consistent with a 0.13% rate of permanent disconnection each month as observed in the sample. Upon disconnection, 21% of households pay all of their remaining balances, which calibrates the share χ of households that are assumed to move to a new dwelling within Manila. Moreover, 12 months before disconnection, households are assumed to learn if they will have to pay their remaining balances upon disconnection. This assumption is consistent with households accelerating their unpaid balances starting 12 months before disconnection.[23]

The estimation routine solves the household's problem in equation (4) through backwards induction. In the last month $T = 384$, the routine finds the combination of water and standard assets that maximize utility in the scenario where households must pay both their standard debt and their water debt. The routine also solves for water and standard assets in the scenario where households do not have to pay their water debt. Taking these choices as given, the routine then steps back to month $T - 1$ and finds the combination of assets (and connection status) that maximizes current utility plus discounted future utility separately for both scenarios. In the thirteenth month before disconnection, households do not know whether they will have to pay their water debt. Therefore, their expected future utility in this month equals expected future utility under each scenario weighted by their probabilities of occurring. Repeating this process for earlier months brings households to a steady state mapping of current assets/connection status to future assets/connection status.

The routine allows households to choose across 40 standard asset values and 40 water asset values.[24] Standard assets values are evenly spaced between borrowing and saving up to twice average household income. In simulations, households are never observed borrowing the maximum amount and are observed saving the maximum

[21] In US contexts,Gourinchas and Parker [2002] use a similar structural approach finding a lower discount rate of around 5% while Laibson et al. [2007] recover a discount rate of around 15%.

[22] The literature provides a range of estimates for γ which are above, below, and around one. Barseghyan et al. [2013] use insurance choices in the US to estimate a γ between 0.21 and 0.37 while Beetsma and Schotman [2001] use a natural experiment from a game show to estimate γ ranging from 0.42 to 6.99. Carvalho et al. [2016] leverage an experimental setting in Nepal to estimate ρ equal to 0.63. Given these estimates, assuming ρ equal to one implies a moderate curvature of the utility function and is relatively close to a comparable estimate from a development economics setting.

[23] Figure 1 in Appendix 8.3 plots average unpaid balances in the 36 months before permanent disconnection, finding an increasing trend that accelerates within 12 months of disconnection.

[24] Estimates are similar using denser grids with results available upon request.

amount in less than 1% of months. Water assets are evenly spaced between 0 and borrowing up to the 99th percentile of observed water debt, which is equal to 16,082 PhP. In simulations, households are observed borrowing the maximum amount of water debt in less than 0.1% of months.

The estimation strategy uses a simulated method of moments approach. This method begins with an initial guess of values for the water preference, the fixed cost of being disconnected, and the risk of receiving a disconnection warning. The method then computes the optimal path of asset choices and consumption given these parameters. Next, the method takes 384 month random sequences of income and disconnection warning states and computes the savings and consumption profiles for 50 households. Finally, the method computes three moments – average consumption, average unpaid water bills, and average time spent temporarily disconnected – for these simulated households and compares these simulated moments to moments observed in the data. The method repeats this process updating the initial parameter guesses in order to minimize the sum of squared distances between simulated and true moments.

Table 3. Calibrated and Assumed Parameters

Mean Income (PhP)	$\bar{y}$	21,907	Pasay City Household Panel Survey
Income Coefficient of Variation	θ	0.52	Pasay City Household Panel Survey
Interest Rate on Standard Borrowing	r	9.5%	Consumer Finance Survey for Manila
Tariff	$(p_1 + p_2 w)$	$(17.6 + 0.3w)$	Estimated price by water usage (See Appendix 8.4 for details)
Discount Rate	δ	0.5%	In range of structural estimates from literature†
Coefficient of Relative Risk Aversion	γ	1	In range of structural estimates from literature$^{\diamond}$
Household Water Account Length	T	384	Implied by 0.13% of households disconnecting each month
% of Households Remaining in Manila	χ	21	Households who pay all balances upon permanent disconnection

All measures are monthly. Annual rates are converted to monthly rates as follows: Monthly Rate = $(1 + \text{Annual Rate})^{1/12} - 1$

† See Andreoni and Sprenger [2012], Laibson et al. [2007], and Gourinchas and Parker [2002] for structural δ estimates.

$^{\diamond}$ See Barseghyan et al. [2013], Beetsma and Schotman [2001], and Carvalho et al. [2016] for structural λ estimates.

Table 4 provides the estimation results. The Cobb-Douglas preference for water consumption is estimated to be 54.5, which is consistent with households' observed budget share dedicated to water in Manila. The estimated income shock of 0.342 implies that household income either increases or decreases by 34.2% of its average with 50% probability each month. This estimate can also be interpreted as measuring the coefficient of variation (CV) of income and falls on the lower end of previous estimates in the literature.[25] Hannagan and Morduch [2015] use monthly financial diaries in the US to calculate CVs of 0.39 for average households and 0.55 for households below the poverty line. Using household surveys from Mexico, Amuedo-Dorantes and Pozo

[25]The coefficient of variation (CV) measures the standard deviation of monthly household income divided by average household income (Hannagan and Morduch [2015]).

[2011] calculate CVs between 0.29 and 0.46.

The estimation recovers a fixed cost of being disconnected of 182.0 PhP/month. Previous research uses a static, structural approach to estimate a long-term monthly fixed cost from using alternative water sources of 130 PhP/month (Violette [2019]). While these estimates fall in a similar range, this paper produces a larger estimate of the fixed-cost likely because sudden disconnections leave little time for households to invest in finding low-cost alternative sources for water. This estimate is also likely to capture the one-time 200 PhP fee charged to households for reconnection.

The borrowing rate from standard assets is estimated to be 2.2% per month, which implies an annual interest rate of 29.8%. This estimate is substantially lower than the 20% per month interest rate that Karlan and Zinman [2009] document as being commonly charged by moneylenders in Manila. Despite this high interest rate, Karlan and Zinman [2009] document that at least 30% of their sample of microentrepreneurs report taking credit from moneylenders. The estimated borrowing rate of 2.2% is more similar to microloans of 1,000 PhP at 2.5% monthly interest offered to rural Filipino households as part of a microfinance experiment conducted by Giné and Karlan [2014].[26]

Table 4. Estimates

Parameters		Estimates
Water Preference	α	54.5
		(0.00)
Fixed Cost of being Disconnected (PhP)	f	182.0
		(0.0)
Collection Rate	λ	0.022
		(0.0055)
Households		33,166
Household-Months		2,021,144

Standard errors in parentheses are bootstrapped at the household-level.

Table 5 provides both moments in the data used for estimation as well as other moments to help understand the fit of the model. While the model is able to almost exactly match average usage and outstanding balance, the model has more difficulty matching the slow decline in disconnection rates observed after delinquency visits. The model

[26] The annual interest rate of 29.8% well exceeds the average 13 to 25% range offered by microfinance providers worldwide surveyed by Cull et al. [2009]. Two possible reasons for this discrepancy are that (1) institutional reasons unique to Manila may limit lenders' abilities to offer low rates and (2) subsidies may allow many microfinance providers to offer below-market interest rates.

instead predicts that households who disconnect in response to a delinquency visit will quickly reconnect over the following four months. One explanation for this discrepancy may be that the distribution of income shocks does not allow for serial correlation so that households are assumed to quickly recover from negative shocks in the model. In reality, households may be temporarily disconnecting in response to longer-term negative income shocks like job-loss or illness. A similar pattern exists for disconnection conditional on being at least 90 days overdue when visited.

how impossible is it to include this serial correlation in the model/comp

Table 5. Model Fit

Moments	Data	Predicted
Used in Estimation		
Consumption (m3)	24.2	24.2
Balance (PhP)	1235	1215
Disconnected	0.0152	0.0154
Unused in Estimation		

"Disconnection" is measured before permanent disconnection.
"Corr." stands for correlation.

The model has difficultly matching moments that were not used in the estimation. Since log-utility encourages households to smooth their consumption over time, this model predicts very little variation in water usage over time. By contrast, high observed variation in usage is likely driven by the fact that households face idiosyncratic shocks to their water demand each month as household members travel for work, other families come to visit, or Manila experiences a heat wave. A more complete model may include a term for indiosyncratic water shocks although it is unclear whether these shocks would substantively affect the model's predictions for income smoothing across time. While poorly matching variation in usage, the model is able to generate over half of the observed variation in outstanding balances.

The data find a positive correlation between usage and outstanding balances, which suggests that households may take on water debt to fund extra consumption in months where they face large, positive shocks to their water demand. In the model, positive income shocks reduce demand for water debt and increase demand for water. At the same time, negative income shocks reduce demand for water while increasing demand for water debt. On net, the model finds zero average correlation between outstanding balances and usage.

This is your hook for the intro, but also this could be

To build intuition, Figure **??** provides 100 time periods of simulated data from the model. These 100 time periods are chosen to center around the first disconnection occurrence in the 2,000 month random sequence of states used in the estimation. The first panel in Figure **??** indicates the cumulative, exogenous income shocks faced by the household. This sample begins with a long period where negative income shocks occur more frequently than positive income shocks. Positive shocks only begin to outweigh negative shocks at around 50 months. Indicators for when the household receives delinquency visits as well as whether it chooses to remain disconnected are also nested in this first panel. Over the course of 100 months, the household experiences three visits, the second of which leads the household to disconnect for around 12 months. This disconnection corresponds to a period where the household has accumulated a long string of negative income shocks.

The second panel indicates the household's choice of asset position, A_{t+1}, in each month. Asset position closely tracks income realizations as the household increasingly borrows (moving into very negative positions) following the long series of negative income shocks. At around the time of disconnection, the household chooses to borrow the maximum allowed by the grid of assets chosen for the simulation. Positive income shocks then allow the household to borrow less and begin saving at around 60 months.

The third panel indicates household borrowing through unpaid water bills, B_{t+1}. In the beginning, the household increases its borrowing more slowly than with standard assets since each month's increase in borrowing is limited by the size of the household's current water bill. Matching the downturn in income, the household continues borrowing before reaching the maximum borrowing allowed by the grid of assets chosen in this simulation. With few positive income shocks, the household remains at this maximum borrowing level for at least 24 months. When the second delinquency visit occurs at around 40 months, the household is still borrowing the maximum from unpaid water bills and therefore, instead of choosing to pay its full outstanding balance to stay connected, the household chooses to disconnect until it accumulates enough positive income shocks to pay its full water bill around month 55. During the third delinquency visit, the household's outstanding balance happens to be relatively small so it is able to immediately pay in full to remain connected.

The fourth panel indicates household water usage patterns over the same 100 months. Usage begins to spike as the household increases its usage to fund borrowing through unpaid water bills. The largest spikes in usage occur when the household moves to the maximum level of borrowing. Because of the step-size chosen for the asset grid, moving to the largest borrowing level requires a jump in unpaid bills of around 1,000 PhP. Since the average bill is around 600 PhP, the household needs to almost double

Why lumpy/spik Why doesn't usage just go up smoothly?

its usage to fund this jump in borrowing from unpaid bills. These spikes in usage measure the extent to which borrowing from unpaid water bills may distort consumption choices, adding an additional friction associated with borrowing from water bills. After maximizing water borrowing at around 24 months, usage begins to stabilize at lower levels, mirroring the long string of negative income shocks faced by the household. Usage recovers to a higher level after the second delinquency visit before spiking again as the household maximizes its water debt in the last several months.

If this is just a grid-size quirk, don't highlight it like its! Borrowing limit is awkward

6. Counterfactual Policies

To measure how much households value credit from unpaid water bills, I examine how household welfare changes in a counterfactual setting where households are unable to borrow from their water bills. Table 6 includes outcomes for the current setting in Manila in Column (1) and for a counterfactual setting without water borrowing in Column (2), which is captured by raising the interest rate on unpaid water bills to 100% and holding all else equal. The first row calculates compensating variation equal to 50.3 PhP (or 1.1 USD) per household-month associated with losing access to water credit. This estimate suggests that households are indifferent between their current situation and a counterfactual with 50.3 PhP per month in additional income and without access to water credit. Given an average water bill of 671 PhP/month, this estimate would translate into households paying around 7% smaller bills each month.

Eliminating credit access also decreases mean usage by 6.0% as shown by columns (1) and (2) in the second row of Table 6. Eliminating credit access lowers the extent to which households can smooth their consumption over time while also removing the incentive for households to overconsume water in order to finance water borrowing. Given that households spend around 2.0% of their income on water, this estimate is roughly proportional to similar evidence from South Africa where restricting credit access with prepaid electricity meters produced a 13% reduction in usage and where households spend around 8-10% of their income on electricity (Jack and Smith [2016]).[27]

[27] Jack and Smith [2016] also propose other mechanisms that may account for reductions in usage such as transaction costs and intra-household bargaining constraints.

Table 6. Counterfactual Policies

	(1) Current	(2) Prepaid Metering	(3) Revenue Neutral Collection Rate	(4) Utility as a Bank
Compensating Variation		164	-217	-288
Consumption	631	593	660	593
Outstanding Balance	1220	0	8849	8666
Fixed Price	0	29	1	76
Collection Rate	0.21	0.00	0.03	0.00

All values are at the household-month level.

This setting also provides a useful opportunity to simulate the social welfare impacts of popular policies to reduce delinquency. I consider a policy that (1) eliminates borrowing by raising the interest rate on unpaid bills to 100% and (2) adjusts prices to ensure that the utility remains revenue-neutral. The regulatory structure in Manila as well as many other developing cities ensures that prices for water are regulated to exactly cover all production costs (Hoque and Wichelns [2013]).

Eliminating borrowing affects the costs of the utility in four main ways

1. *Opportunity Cost of Lending*: Currently, the utility faces an opportunity cost for the loans extended to households in the form of unpaid bills. Assuming that the utility would have been able to invest this money at an average annual interest rate of 9.5%, the opportunity cost of lending averages 41.5 PhP per household-month, which would be recouped by the utility in a counterfactual without delayed payments.[28]

2. *Delinquency Visit Cost*: Without water borrowing, the utility would no longer need to conduct delinquency visits. Conversations with the utility suggest that travel costs make up the majority of the costs for any service performed on a water meter. Since the utility requires a 200 PhP fee to reconnect disconnected households, I assume that delinquency visits cost the same amount to the utility.

[28]Interest rate reflects the average between 2010 and 2015 as reported by the World Bank Databank.

Conditional on being delinquent, households receive visits in 2.6% of household-month observations, which implies an average delinquency visit cost to the utility of 2.5 PhP per household-month.

3. *Marginal Costs*: The utility reports a marginal cost per cubic meter of consumption equal to 5 PhP.

4. *Disconnection Rebate:* Currently, the utility is exposed to default risk where households that permanently disconnect from the utility often leave large outstanding balances that are never paid. On average, 0.0015 households permanently disconnect per household-month. These households that permanently disconnect leave average outstanding balances of 7,119 PhP. These estimates imply household savings equal to an average of 10.2 PhP per household-month. In practice, households enjoy all of these savings in the final few months that they remain connected. However, since households use water indefinitely in the model, the counterfactual exercise captures these savings by assuming that households receive a monthly fixed disconnection rebate of 10.2 PhP. By evenly spreading these savings over time, this approach is likely to overstate the true benefits to households from leaving unpaid bills. This approach relies on the following additional assumptions

   How is this a cost? I'm confused by this section. Is this real or model assumption or counterfactual?

   - By assuming that households receive fixed rebates, this approach ignores any incentives that households may face to overconsume in their final months connected (since households may behave as if they face an effective price of zero in these months). Appendix 8.6 finds some evidence of overconsumption before permanent disconnection although the short duration and small magnitude of overconsumption suggest that excluding this margin will have little impact on total welfare estimates.
   - Household decisions over when and whether to permanently disconnect from service are assumed to be unaffected by changes in billing flexibility. Since permanent disconnections are likely to be driven by households changing residences, this assumption is consistent with quality of water access having little effect on household location decisions.
   - This approach assumes that under a counterfactual setting with a high borrowing interest rate, households always pay their bills on time even when they are about to permanently disconnect. This assumption may be reasonable since households would only have an incentive to delay their payments

when they are close to permanently disconnecting. Since permanent disconnections are rare, the utility can credibly threaten to disconnect households as soon as they stop paying their bills. This threat would likely ensure that households always pay their bills on time.

To determine price increases necessary to cover these costs, the following expression first calculates the revenue raised through prices, p_1 and p_2, per household-month given income, Y, net of marginal cost, MC

$$REV(p_1, r_b, Y) = \Big(p_1 - MC + p_2\, w^*(p_1, p_2, r_b, Y) \Big)\; w^*(p_1, p_2, r_b, Y)$$

I then solve for the new price intercept, p_1', such that the current revenue is equal to revenue under a counterfactual where the borrowing rate is equal to 100% and the utility enjoys cost savings. This exercise assumes that the government regulator is able to perfectly forecast water demand among all households. Adjusting only the price intercept, p_1', instead of both price terms provides a way of preserving the slope of the tariff structure, which likely reflects equity concerns among policymakers in Manila.

p_1' is chosen to solve the following expression

$$\begin{aligned} \sum_t REV_t(p_1, 0, Y_t) = & \sum_t REV_t(p_1', 1, Y_t - \text{Disc. Rebate}) \\ & - (\text{Opp. Cost of Lending} + \text{Visit Cost} + \text{Disc. Rebate}) \end{aligned}$$

In the counterfactual, cost savings reduce the amount of revenue needed to be raised to stay revenue neutral. At the same time, eliminating borrowing in the counterfactual lowers water consumption, which reduces revenue since prices are well above marginal costs. Table 6 finds that these two effects almost exactly offset each other, producing almost identical prices in the current setting in Column (1) and in the counterfactual without water borrowing in Column (3). Removing water borrowing while keeping similar prices results in a drop in average usage between Columns (1) and (3) that is nearly identical to the drop in usage between Columns (1) and (2).

According to the first row of Table 6, households would require a compensating monthly payment of at least 51.1 PhP in order to move from the current setting in Column (1) to a revenue-neutral counterfactual without borrowing in Column (3). Although prices remain almost identical in Column (3), revenue neutrality ensures that households no longer receive a monthly disconnection rebate of 10.2 PhP, which almost exactly accounts for the difference in compensating variation between columns

(2) and (3).

I then simulate the effects of introducing prepaid metering technologies and adjusting water prices to similarly account for their costs. By requiring households to pay upfront for their water usage, these meters provide an alternative strategy for eliminating unpaid water bills. These technologies have become increasingly popular for both electricity and water utilities throughout the developing world.[29] These technologies may be especially useful in contexts where other factors drive delinquency instead of consumption smoothing. For example, Szabó and Ujhelyi [2015] suggest that low levels of trust in local government and perceptions of fairness may drive some nonpayment behavior. While these factors are not explicitly modeled in this context, this exercise may still provide a useful lower bound for evaluating the welfare effects of prepaid metering programs.

does this constrain my water use? i can only use what i paid for? oh or is it like prepaid cell phones and you just pay more when your balance is running low?

Prepaid meters introduce an additional cost for the utility in terms of purchasing and installing this new technology. Heymans et al. [2014] surveyed eight large water providers that implemented prepaid meters in developing countries and found that each prepaid meter costs about four times as much as a standard meter and requires replacement every 7 years. In the context of Manila, each standard meter costs around 1,500 PhP and is replaced around every 6 years and 3 months, bringing the monthly cost to 20 PhP/month.[30] Assuming that a prepaid meter costs 4 times as much as a standard meter with a replacement rate of 7 years, the estimated monthly cost of a prepaid meter would be 71 PhP/month. Therefore, prepaid meters imply an additional cost of 51 PhP/month per household.[31]

Column (4) of Table 6 includes the results of the prepaid metering counterfactual. To cover the much higher costs of prepaid meters, the price intercept, p_1, increases by around 33.2% as indicated by the fourth row. Households also no longer receive a disconnection rebate of 10.2 PhP per month. With higher prices and without water credit, households lower their consumption by 17.0% under prepaid metering compared to the current setting in Column (1). In order to be indifferent between the current setting and a counterfactual with prepaid metering, households would need to receive 225.2 PhP/month in compensation. Taken together, these results provide suggestive

[29] See Jack and Smith [2016] and Northeast Group [2014] for electricity utilities and Heymans et al. [2014] for water utilities.

[30] The utility provided additional documentation of their costs and frequency of meter replacement for residential households.

[31] Heymans et al. [2014] also report that the fixed administrative costs of installing and monitoring new meters account for less than 4% of the total costs of switching to prepaid meters while the bulk of the expenses come from purchasing new meters. By focusing on meter replacement, this exercise is likely to capture the majority of switching costs associated with prepaid metering.

evidence that prepaid metering would reduce welfare substantially in this context.

7. Conclusion

Prepaid meters for electricity already compose over 27.5% of residential meters in Sub-Saharan Africa and are predicted to grow to 52.8% by 2024 (Northeast Group [2014]). Similarly, by planning to install over 300,000 prepaid meters, the Botswana Water Utilities Corporation provides an example of the growing use of this technology in the water sector (Heymans et al. [2014]). Policy proposals for prepaid meters often emphasize how this technology ensures cost-recovery for utility providers. At the same time, households stress how "water is a need, but money is not always available" and how "postpaid gives you more time to find the money" in qualitative evidence documented by Heymans et al. [2014]. These anecdotes suggest a potentially important role for billing flexibility in allowing households to smooth consumption.

This paper builds a dynamic model of household consumption smoothing to measure the extent to which households value billing flexibility. Estimates imply that households' valuation of flexibility is on the order of 7% of their monthly water bills. Counterfactual exercises further find that policies to eliminate nonpayment — raising interest rates on unpaid bills and prepaid metering — do not produce enough cost savings to justify their negative impacts on household consumption smoothing. On net, these policies are predicted to reduce social welfare by between 1.1 and 5.0 USD per household-month.

i'm still not sure i get this... what are the cost savings?

In focusing on the role of consumption smoothing, this approach abstracts away from other channels by which nonpayment may affect welfare. First, high rates of nonpayment may weaken incentives for utilities to invest in and extend access to high quality infrastructure. While regulators in Manila successfully ensure universal access and service quality, McRae [2015] documents how electricity providers in Colombia often shirk on infrastructure investments in areas where they face high levels of nonpayment, which are also often underprivileged areas. Second, policing nonpayment through unexpected disconnections may also have unintended health consequences (Franklin and Kurtz [2017]). The US Department of Health and Human Services [2019] lists a series of state-level policies restricting disconnections, especially in months with extreme temperatures, for public health reasons. Finally, nonpayment may provide a way for households to voice their dissatisfaction with a utility as well as local government. Szabó and Ujhelyi [2015] find evidence that reaching out to consumers on behalf of a water utility increased payments from households motivated by a sense of

i would add more oomph to this. i think

reciprocity.

8. Appendix

8.1. Sample Construction

Merging the full sample from the connection survey to the billing data yields an initial population of 4,678,420 connection-months as described in Table 7. Non-residential accounts are first removed to ensure that results apply to household-level decisions. Due to some data inconsistencies, payment records are missing for some connections, which are excluded. Due to leaks, meter replacements, and meter reading errors, connections occasionally experience extremely high meter readings and bills. Consumption records above 200 m3 as well as bills and payments above 80,000 are censored to address these issues. Large negative payments and outstanding balances (due to reimbursements of billing errors) are also excluded due to likely measurement error. Remaining negative payments and balances likely represent refunds to households (possibly due to system errors), which are included to accurately reflect each household's asset position. Households that connect during the sample or have large stretches of missing records are excluded by including only connections with over 30 months of data. Keeping only connections serving single households brings the final sample size to 2,872,815 household-months.

Table 7. Sample Construction

	Observations	Observations Removed
Initial sample	4,678,420	
Keep residential connections (excluding commercial)		632,903
Keep connections with payment records		40,708
Keep months with usage under 200 m3		73,219
Keep bills > -5,000 PhP and < 80,000 PhP		84,048
Keep unpaid bills > -5,000 PhP and < 80,000 PhP		12,087
Keep payments > -80,000 PhP and < 80,000 PhP		0
Keep connections with over 30 months of records		0
Final sample	2,872,815	

8.2. Bill Payments and Delinquency Warnings

The following equation estimates the effect of delinquency warnings on bill payments

$$
\begin{aligned}
Pay_{it} = \alpha + \beta\{\text{own warning}\}_{it} + \\
&\sum_{k=1}^{3} \gamma_k \{\text{warning for k-th nearest HH in same neighborhood}\}_{it} + \\
&\sum_{j=1}^{3} \theta_j \{\text{warning for j-th nearest HH in different neighborhood}\}_{it} + \eta_i + \zeta_t + \epsilon_{it}
\end{aligned}
$$

where i indexes households and t indexes months. Pay indicates bill payments in the same month. Indicators variables signal months where households receive warnings and where their three immediate neighbors receive warnings. Immediate neighbors are considered separately based on whether neighbors reside in the same or different neighborhoods. The specification also includes household fixed effects (η_i) and calendar month fixed effects (ζ_t). Information on the exact location of each household is available for over half of the sample, which is used to measure distances between households.

Table 8 includes the results of this exercise. Receiving a delinquency warning is correlated with large, immediate increases in bill payments around the size of the average bill payment in the sample. Conditional on receiving a warning, households that have immediate neighbors who receive warnings in the same neighborhood also increase their bill payments although the magnitudes are much smaller than the own warning effect. Warnings for the 3rd nearest household have a slightly smaller effect than warnings for the nearest household although warnings for all households are positive and significant. Households do not appear to change their payment behavior when nearby households in different neighborhoods receive warnings, which suggests that the utility follows a neighborhood sweeping strategy.

Table 8. Bill Payments and Delinquency Warnings

	Bill Payment (PhP)
Own Warning	587.51[a]
	(19.73)
Warning in Same Neighborhood for:	
1st Nearest Household	42.36[a]
	(11.67)
2nd Nearest Household	46.63[a]
	(11.06)
3rd Nearest Household	33.56[a]
	(11.67)
Warning in Different Neighborhood for:	
1st Nearest Household	10.97
	(33.01)
2nd Nearest Household	-6.11
	(28.85)
3rd Nearest Household	7.58
	(25.21)
Mean	629.40
R^2	0.286
N	1,148,439

Household and calendar-month fixed effects are included. Standard errors are clustered at the household level. [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

8.3. Average Unpaid Bills Before Permanent Disconnection

8.4. Tariff Structure and Approximation

Table 9. Example Residential Tariff As Presented to Consumers

Usage (m3)	Price (PhP)
Under 10	104.79 /conn.
Over 10	181.31 /conn.
Next 10	19.20 /cu.m.
Next 20	25.52 /cu.m.
Next 20	33.94 /cu.m.
Next 20	40.73 /cu.m.
Next 20	45.99 /cu.m.
Next 50	50.88 /cu.m.
Next 50	55.53 /cu.m.
Over 200	57.86 /cu.m.

Mean tariff 2010-2015 with value added tax.
"conn." refers to connection.
"cu.m." refers to m3/month. 50 PhP~1 USD

Figure 1. Average Unpaid Bills in 36 Months Before Permanent Disconnection

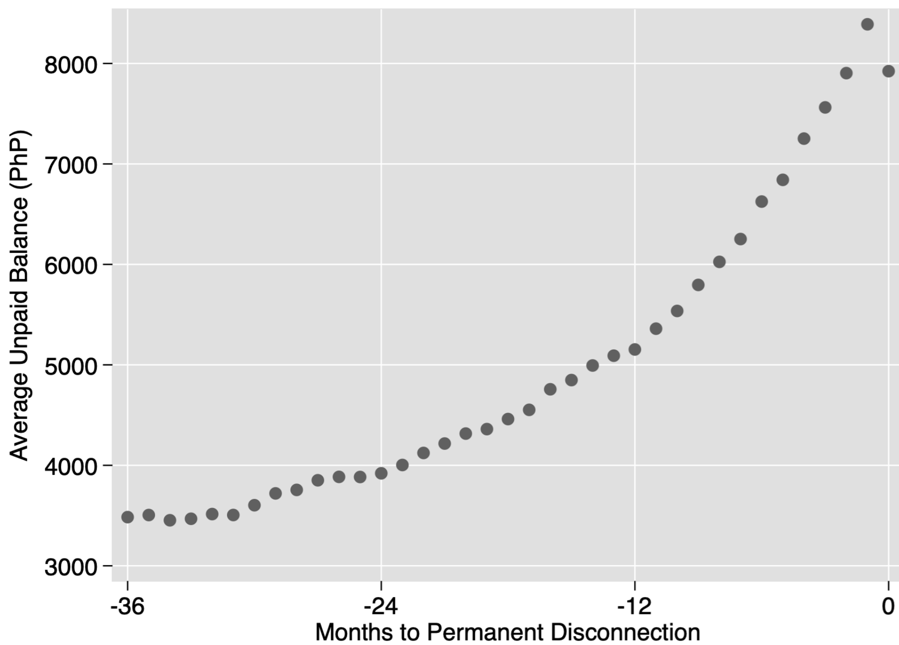


Table 9 provides the monthly tariff structure as it is presented to consumers. Consumers face a fixed price as well as marginal prices for any usage above 10 m3. The regulator gradually adjusts prices at roughly yearly intervals in order to ensure that the utility is able to exactly cover its costs. The marginal price is highly non-linear, accelerating quickly at low usage levels before slowly increasing at high usage levels. To achieve a tractable approximation of this price schedule, Table 10 fits a simple regression model predicting average price as a function of an intercept, p_1, and monthly usage levels, p_2. This model predicts that a increase in monthly usage of 10 m3 results in an increase in average price of 2.2 PhP/m3.

Table 10. Average Price and Monthly Usage

	Avg. Price: $\frac{\text{Bill (PhP)}}{\text{Usage (m3)}}$
Usage (m3)	0.29[a]
	(0.00)
Intercept	17.57[a]
	(0.05)
Household-Months	1,861,200

[c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

8.5. Alternative Income Test

The following equation empirically tests whether income is more correlated with bill payments than with consumption

$$\Delta Y_{bq} = \beta\, \Delta\textsc{Income}_{bq} + \gamma_q + \varepsilon_{bq}$$

where $\textsc{Income}_{bq}$ is proxied by the quarterly change in average labor earnings from Quarterly Labor Force Surveys where q indexes 28 quarters from 2009 to 2015. Average earnings are computed for 80 unique bins, b, defined by combinations of 4 sub-municipalities, age in 5 year intervals, and whether college educated in order to merge individuals from the Labor Force Survey to individuals water connection owners from the water connection survey. ΔY_{bq} is the quarterly change in either average water consumption (measured by the water bill in PhP) or average water bill payments (in PhP) by bin-quarter. Standard errors are clustered at the bin-level.

Column (1) of Table 11 finds a positive but statistically insignificant correlation between income and consumption. Due to measurement error in income, the small point estimate of 0.0007 likely underestimates this correlation. Measurement error in income is likely to be substantial both because only around 55 incomes are observed per quarter-bin in the Labor Force Survey and because bins are constructed from coarse demographic categories that may only loosely reflect household incomes. Despite this potential measurement error, Column (2) finds a statistically significant correlation between bill payments and income that is six times larger than the correlation between income and consumption. These results provide suggestive evidence of consumption smoothing where households flexibly adjust their payment patterns in response to income shocks without changing their water consumption.

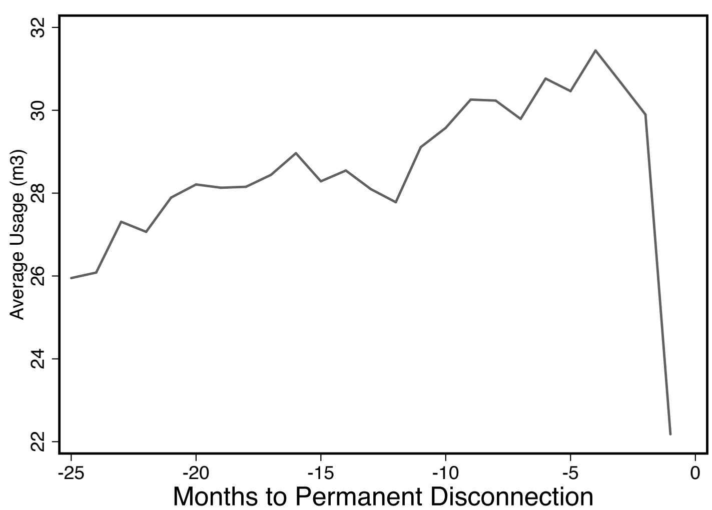
Table 11. Correlations of Income with Consumption and Payment Patterns

	(1) Δ Consumption	(2) Δ Payment
Δ Income	0.0007	0.0042[a]
	(0.0011)	(0.0013)
Mean	651	640
R^2	0.451	0.154
N	1,516	1,516

All units are in PhP. Quarterly fixed effects are included. Standard errors are clustered by age-group, sub-municipality, and whether college educated (80 units). [c] $p<0.10$,[b] $p<0.05$,[a] $p<0.01$

8.6. Usage Before Permanent Disconnection

Figure 2. Average Usage in Months Before Permanent Disconnection



Permanent disconnection is defined as households disconnecting and remaining disconnected for the at least the last two years of the sample. Negative months indicate months leading up to permanent disconnection. Months with zero usage are dropped because households may leave months with zero consumption before the company disconnects them.

8.7. Income Coefficient of Variation

Table 12. Income Coefficient of Variation Estimates

	(1) Raw	(2) Adjusted
All	0.566	0.523
By Income Tercile		
T1	0.557	0.609
T2	0.552	0.474
T3	0.588	0.487
Demographic/Occupation Controls	No	Yes
Households	27,343	27,343
Years	2008, 2011	2008, 2011

The Coefficient of Variation (CV) for each household (HH) is $\frac{2|y_{2011} - y_{2008}|}{y_{2011} + y_{2008}}$ where y is HH income. Estimates take the mean CV across HHs. Income terciles are computed by mean HH income.
Adjusted CV is $\frac{2|\overline{y}_{2011} - \overline{y}_{2008}|}{y_{2011} + y_{2008}}$ where $\overline{y}$ is residual income controlling for HH employment by skill-level, oldest HH age, HH size by education, year, and HH fixed effects.

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